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# AUTOMATIC FINGERPRINT VERIFICATION SYSTEM - DIGITAL IMAGE PROCESSING ALGORITHM -



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## Abstract

Fingerprint is used as means of person verification in view of that it has the highest reliabilty and safety.

Whole verification process is consisted of 3 stages, namely, of the preprocessing stage including smoothing, binarization, and thinning, the feature extraction stage including restoration and extraction of minutiae and its features, and the matching stage including minutiae registration and judge.

Tests for this research with 325 pairs of fingerprint resulted in 100 % of seperation which in turn is turned out to be the reliability of this algorithm.

## 1. INTRODUCTION

3 kind of methods as follovs can be thought as the personal identity verification system :

1) Method by person's thing in hand. (ID CARD, STAMP)
2) Method by registered memory. ( PASSWORD )
3) Method by physical features of person's body. ( Finger-print, Palm-print )

Among these method, method 3) has the highest security because it has high reliability ( few possibility of rejecting the person himself) and high safety ( few possibility of accepting other person ). And, because of the characteristics of " Everybody has the different one." and " It's unchanged during one's life.", the fingerprint is the most effective means among features used by method 3).

Generally automatic fingerprint recognition systems are classfied into the identification system and the verification system. Identification system is the same as applied in the police system. It is the "1:N" searching system that finds fingerprint data equal to the input data among the multiple data. Verification system is the "1:1" judging system whether the input fingerprint with the ID# is the same with the pre-registered one or not. This is applied to the enterence control system of important institutions.

The processing algorithm of identification system[1] is almost consolidated and reached the pratically useful stage. Several verification systems[2,3,4] are also developed, but they have several problems in practical applications in view of the cost and the precision.

The purpose of this study is to develop the verification system based on PC level. This paper describes the fingerprint input system of lov cost and of high S/N ratio and the prototype of recognition algorithm to solve above problems.

## 2. OUTLINE of PROCESSING

As shown in <Fig.1>, which is the flov of processing, largely 3 stages are involved.

The 1st stage is the pre-processing. As the result of this stage depends on the quality of the input image, the input system is also discussed in this stage.

The 2nd stage is the feature extraction. First in this stage, the restoration on the thinned image is considered. Next are extracted minutiae, its features and the relations. Minutiae means ridge-ending and bifurcation, and minutiae's features are its coordinates and directions as shovn in <Fig.2>. Fingerprint consists of ridges and valleys. 'Ridge-ending' is the point each ridge is terminated to, and 'bifurcation' is the point it is divided from. Considering the local coordinates system centered on the feature point and assigned Y-axis as the direction of its points, the 'relation' is defined as the number of ridges existed between two nearest minutiae on each local quadrants[1].

The 3rd stage consists of two kinds of processing. At first, two matching-required



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# PROCEEDINGS

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images are transformed to the same coordinate system, next the matching score is calculated which is the similarity between two images.

## 3. PRE-PROCESSING

### 3-1. INPUT SYSTEM

There are generally known of three kind of the input methods as follows :

1) method to directly input fingerprint into a sensor[2].
2) method by light way separation or total reflection of the prism[3].
3) method to use the difference of distance between ridge and valley by laser[4].

On the other hand, high S/N ratio, small size and weight, and low cost should be considered in practical application of the input system. In this study, considering above conditions, the input system using the total reflection method of prism is developed. Its configuration is shown in <Fig.3>.

Two LEDs are used as light source. This input system used the CCD camera and produces the original input image of size of 512*512 pixels, 8 bits per pixel.

An original image from this system is shown in <Fig.4>.

### 3-2. SMOOTHING

Original Input image has a many noises caused from sensor noise, perspiration aperature of finger, dust on the prism surface and others. In order to eliminate these noises, the average filter of 3 * 3 pixels window is applied.

### 3-3. BINARIZATION

The smoothed image has partial shadings caused from the light source of the input system and the unequality of finger pressure. The local binarization by the local thresholding could get rid of this effect.

The whole image is divided into a lot of local areas of 12*12 pixels. In the 1st step, the average and deviation value should be calculated and then separates the fingerprint region from background region based on the deviation value. In the 2nd step, it separates the ridge from the valley by threshold value, which is the average value.

The result of binarization is shown in <Fig.5>.

### 3-4. THINNING

Although features can be extracted directly from the binary image, this process would be low accuracy. From this reason the thinning algorithm of Hilditch [5] is done in this study.

The result of thinning is shown in <Fig.6>.

## 4. FEATURE EXTRACTION

### 4.1. Restoration on the Thinned Image.

Thinned image frequently contains some odd structures which can't be existed on the real fingerprint.

As shown in <Fig.7>, these structures can be grouped into two pseudo minutiae such as pseudo ridge-ending and pseudo bifurcation. Two of these pseudo minutiae are associated within a distance to be classed as follows :

i) cutted-line
ii) short-line
iii) avn
iv) bridge

In this paper, a whole thinned image is divided into several local area with the size of 61*61 pixels. Starting with the local area of the better image quality, restoration is processed step-by-step suited for the area's structures. The details are followed ;

1) Joining the cutted line.

Assume two ridge-endings which has less than a distance of 'R1' as in <Fig.8>. Under the local rectangular coordinate system based on the one ridge-ending, if the other ridge-ending is included within the range of the following equation (4.1), then two ridge-endings are joined.

$$Yi \geq a * Xi^{b} \quad \text{.....(4.1)}$$

where, a, b : constant.
Xi, Yi : local coordinate of the ridge-ending 'i's.

2) Elimination of 'Short-Line' and 'Avn'.

If one ridge-ending is connected to another ridge-ending within a distance of 'R2', then this line is considered as 'short-line', and if one ridge-ending to one bifurcation then so as 'avn'.

3) Elimination of Bridge.

At first, it is needed to calculate the complexity for the bifurcation with the equation (4.2) followed.

$$A = 2 * FB1 - (1/2) * FB2 - 1 \quad \text{.....(4.2)}$$

where, A : complexity.
FB1 : number of other bifurcation connected to the concerned bifurcation.
FB2 : when FB1 is more than 2, number of other bifurcations within a distance of 'R3'.

The result of the restoration is shown in <Fig.9>.

4.2. FEATURE EXTRACTION.

Ridge-ending and Bifurcation, which is used as feature point in fingerprint recognition system, are detected with following equation (4.3).

$$CN = \sum_{i=1}^{8} | M(i) - M(i+1) | \quad \text{.....(4.3)}$$

where, CN : crossing count number.
M(i) = 1 : if the pixel included on ridge.
0 : others.

'i' is the array order of pixels as <Fig.10>, and for the ridge-ending or the bifurcation 'CN' values 2 or 6 respectively.

Feautures of each minutiae are its coordinates, the direction and the relation. The coordinates are detected on the rectangular coordinate system as illustrated on <Fig.2>.

The directions are defined as follows :

1) Direction of ridge-ending.
If the concerned ridge-ending has the coordinates of (X1,Y1) and the one point which has a distance of 'R4' on the same ridge line has the coordinates of (X2,Y2), then the direction is defined as follows :

$$\theta 1 = \cos( D1 / D ) \quad \text{.....(4.4)}$$

where, $D1 = X1 - X2$
$D2 = Y1 - Y2$
$D = \sqrt{D1**2 + D2**2}$

2) direction of Bifurcation.
As in <Fig.2>, the direction of the bifurcation is the direction of one ridge except two ridges which have the smallest inner angle.

Finally, the relation is extracted.

## 5. MATCHING

5-1. Registration.

Registration is a procedure to transform the coordinates of the images so that the images are overlapped correspondingly. The measures used in this procedure are as follows.

<1> Features of the minutiae themselves :
i) type .... ridge-ending or bifurcation
ii) coordinates
iii) direction
> Features between two minutiae :
i) Relation.
ii) The angle from the X-axis to the neighbor in the local X-Y plane.
iii) Features of the neighbors :
a) type.
b) coordinates.
c) direction

These features can be classfied into three classes.
1) Class-1 : measures independent of rotation and displacement.
<1>-i, <2>-i, <2>-ii, <2>-iii-a
2) Class-2 : measures independent of displacement.
<1>-iii, <2>-iii-c
3) Class-3 : the others

With these features, the coordinate of the input image is transformed as following.

Step-1 : With the class-1 features, find the candidates of geometric correction points of the transform.
Step-2 : With the calss-2 features, eliminate inappropriate candidates having large deviations over a certain threshold in cluster of the difference of pair directions.
Step-3 : After further elimination of unprobable pairs with the class-3 features, the coefficients of the Affine transform are calculated by LSE (Least Square Error) method making use of the remained minutiae pairs.

The input and file image, before and after registration, are shown in <Fig.11> respectively.

5.2 Matching score calculation

Making use of the positions and directions of the reliable minutiae pairs,

the matching score is calculated.

$$S = ( 2 * S1 ) / ( F1 + F2 ) \quad .....( 5\text{-}2 )$$

where,
- S1 : the number of minutiae pairs within certain threshold value of position and direction.
- F1 : the number of the minutiae of the input image.
- F2 : the number of the minutiae of the file image.

## 6. Discussion

Experiments with 325 pairs of fingerprints were performed to certify the feasibility of the algorithm. As shown in <Fig.12>, the separability of the matching scores with the same fingers and different fingers was only 30 % before registration, but it increased up to 100% after registration. Therefore, it turned out to be feasible.

The processing time takes about 37 minutes for the total processing by NEC PC 9801 E. The processing time might be shorten by :

1) the use of image processor.
2) the use of fingerprint input guide, which simplifies the registration procedure.
3) the enrollment procedure more sophiscatedly implemented, from which makes more enrolled various information and data to be available to simplify the verification procedure.

## References


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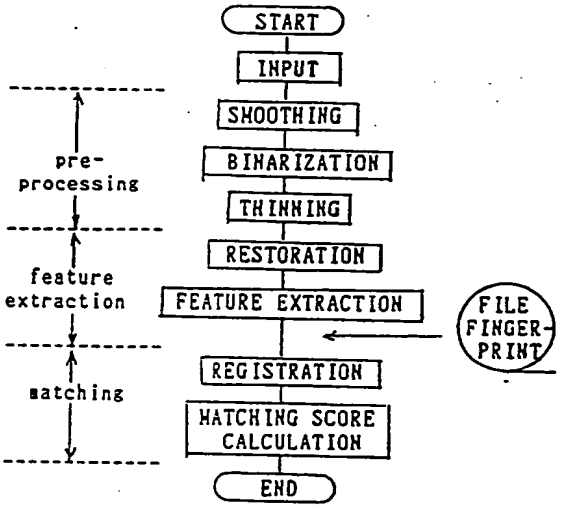
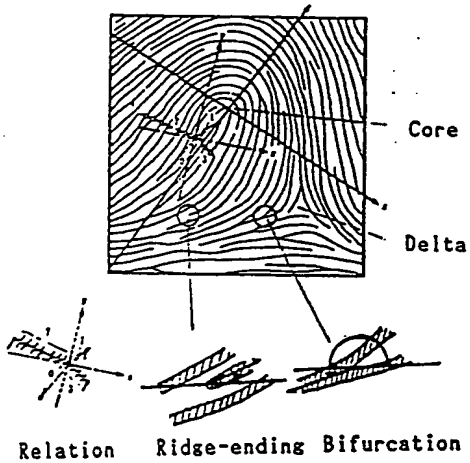
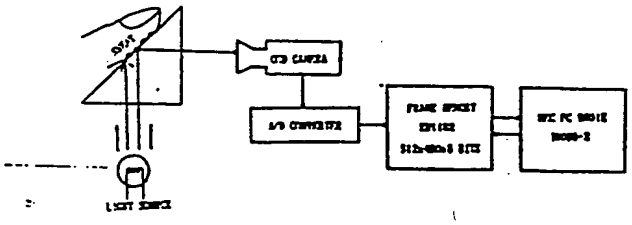



<Fig.1> Flow of Processing.




<Fig.2> Minutiae and its Features.

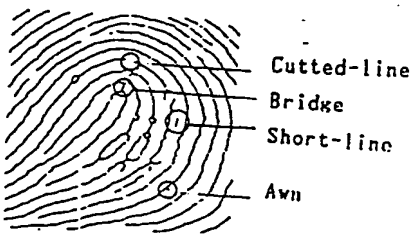


<Fig.3> Configuration of Input System.

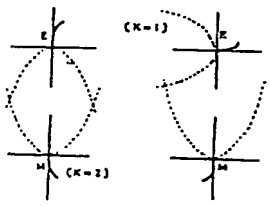
<Fig.4> Original Image.

<Fig.5> Result of Binarization

<Fig.6> Result of Thinning.

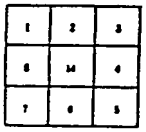



<Fig.7> Pseudo Minutiae.

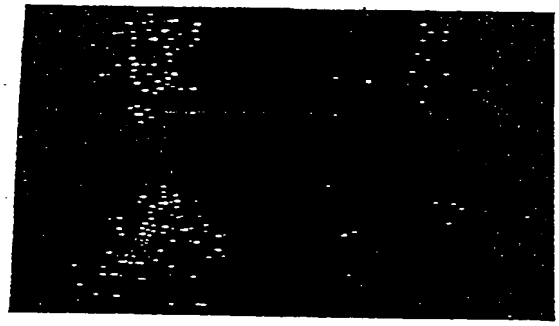



<Fig.8>
Joining of Two Ridge-endings.

<Fig.9> Result of Restoration.

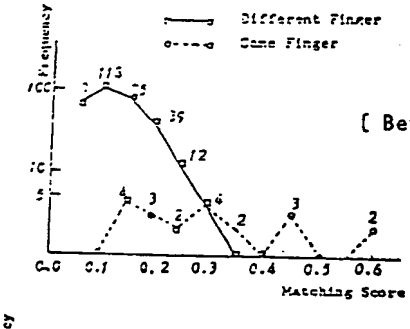


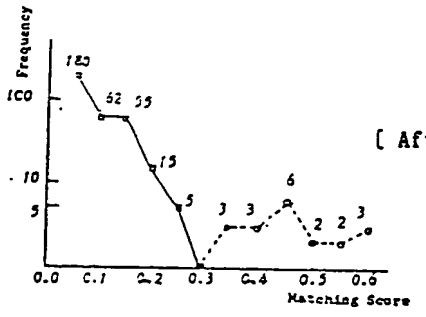
<Fig.10> Array order.



[ Before ] [ After ]

<Fig.11> Registration.




<Fig.12> Distribution of Matching Score.